Playing Nice Across Time & Space

Tools, Methods and Tech for Multi-Location Multi-Decadal Teams

mike.conroy@nasa.gov

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A Little History

- I have been around the Modeling, Simulation, Visualization and Information Technologies space for over 25 years
  - They are grand, challenging, disruptive, ever changing and incredibly powerful. They grow more so every day.
  - And, like any sharp tool, they have sharp edges.
- I would like to share some "Observations" from those years
  - As in Lessons Observed vs. Lessons Learned
  - And, I would appreciate your thoughts on any that I may have missed

Who We Were

- Mike Conroy
  - Manager, Constellation, SE&I, SAVIO, Software SIG, Modeling and Simulation Team (MaST)
  - Used to:
    - Lead CxP Data Presentation and Visualization
    - Lead Kennedy Operations Simulation
    - Be part of OCE Engineering Processes Team (ISE)
      - Several other 3 letter words as well

- Rebecca (Bec) Mazzone
  - Manager, Constellation, SE&I, SAVIO, Software SIG, MaST, Data Presentation and Visualization (DPV)
  - Used to:
    - Lead Distributed Observer Network Project within DPV

Time and System Design

- Apollo First Lunar Launch
  - Mike was there
  - No Bec Yet
- Shuttle STS-1
  - Mike was in college
    - Trying to be a NASA Co-Op
  - Still No Bec; getting close
- Constellation / Exploration
  - Mike will be gone before first Lunar Launch
  - Bec will retire before people got to Mars

How To Play Nice

- The Game is:
  - Multi-Decade, Massive, Complex System Conception, Design, Development and Operations
  - Targeted towards a hostile and unforgiving environment
  - With a gifted, diverse and distributed group of friends
  - With the goal of getting as far off the planet as possible

- The Rules Come From:
  - Physics / Teams / Process / Science / Story
  - Time / Distance / Culture / Goals / Generations

Some Definitions (2001'ish, still apply)

- We Model
  - We represent the **thing** we want to study
  - With as much detail as is necessary for that study

- We Simulate
  - We represent **behavior** of the thing(s) we want to study
  - With as much detail as is necessary for that study

- We Decide
  - We look at the thing(s), their behavior(s), **determine** the next step(s) and **communicate** the results of the study
  - With enough detail for that study to be used or re-used

Design Process Observation

"The" System Engineering Chart

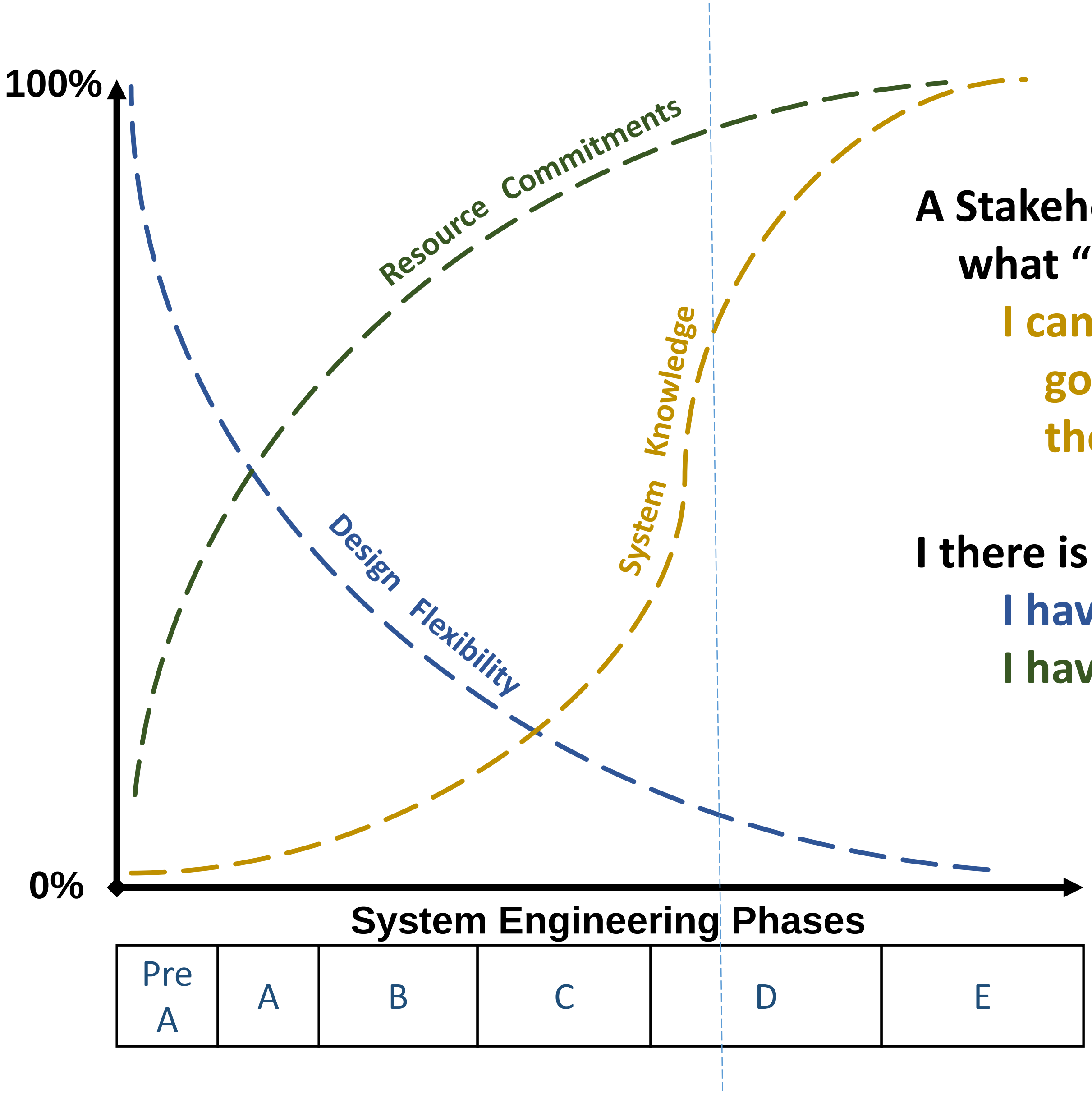
We Have Lifecycle Phases

- Pre-Phase A, Concept, Studies
  - Feasible concepts, simulations, studies, models, mockups
- Phase A, Concept and Technology Development
  - Concept definition, simulations, analysis, models, trades
- Phase B, Preliminary Design & Technology Completion
  - Mockups, study results, specifications, interfaces, prototypes
- Phase C, Final Design, and Fabrication
  - Detailed designs, fabrication, software development
- Phase D, System Assembly, Integration and Test, Launch
  - Operations-ready system with related enabling products
- Phase E - F, Operations and Sustainment, Closeout

We have Lifecycle Elements

- Knowledge
  - What we know about the thing(s) we will ultimately need
  - Ideally we know enough, soon enough, to make a difference
- Flexibility
  - Our ability to actually make a decision
  - Ideally this happens when we know enough to make a good one
- Commitments
  - The results of the decisions, when we decide things we cannot un-decide
  - Ideally our commitments are based on good decisions

The Elements Change Across Time



A Stakeholder wants to know what "It" will look like.

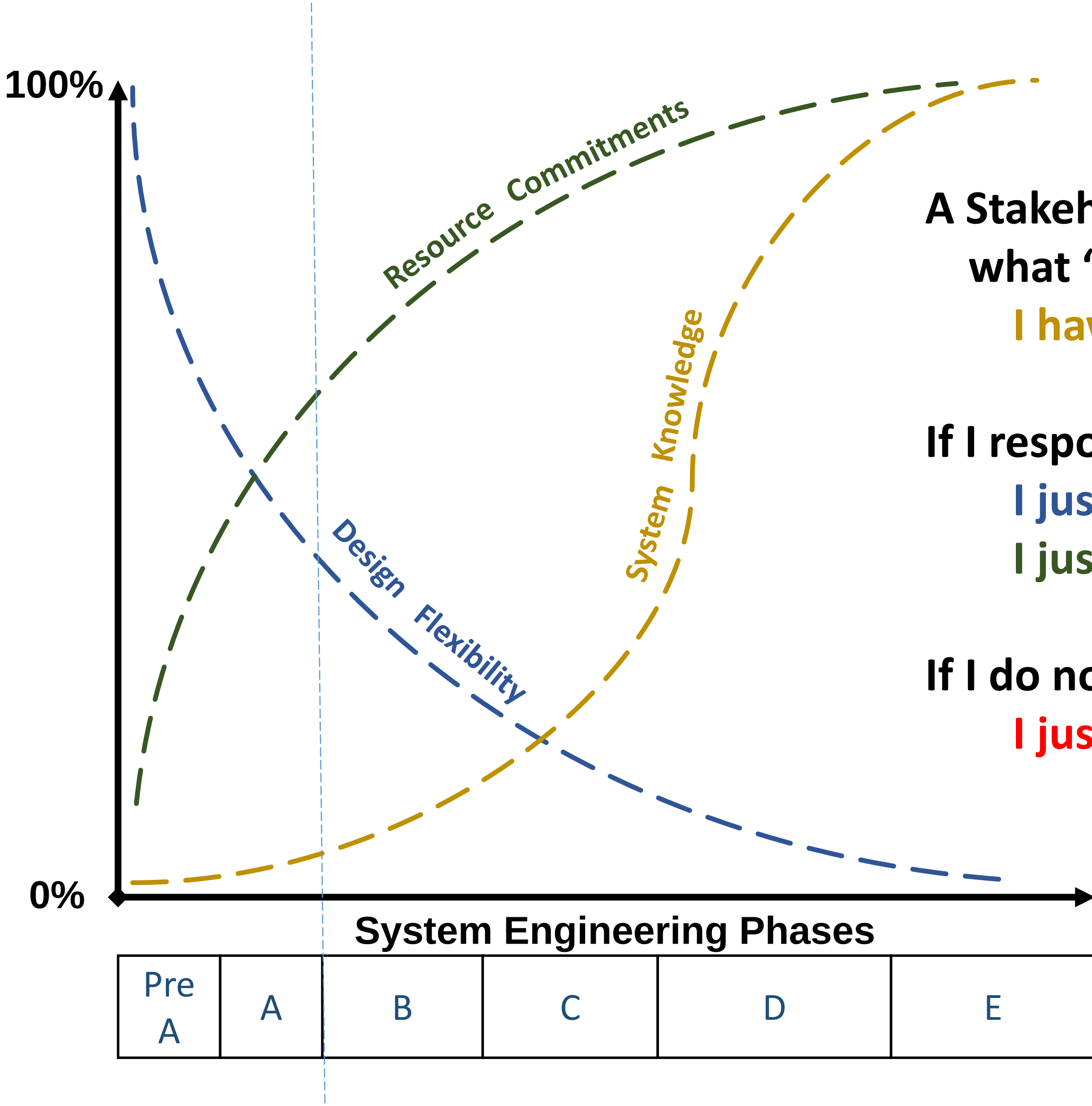
I can show them pieces going together and tour the floor

I there is a change:

I have no design flexibility

I have no money

The Elements Change Across Time



A Stakeholder wants to know what "It" will look like.

I have no system knowledge

If I respond:

I just lost design flexibility

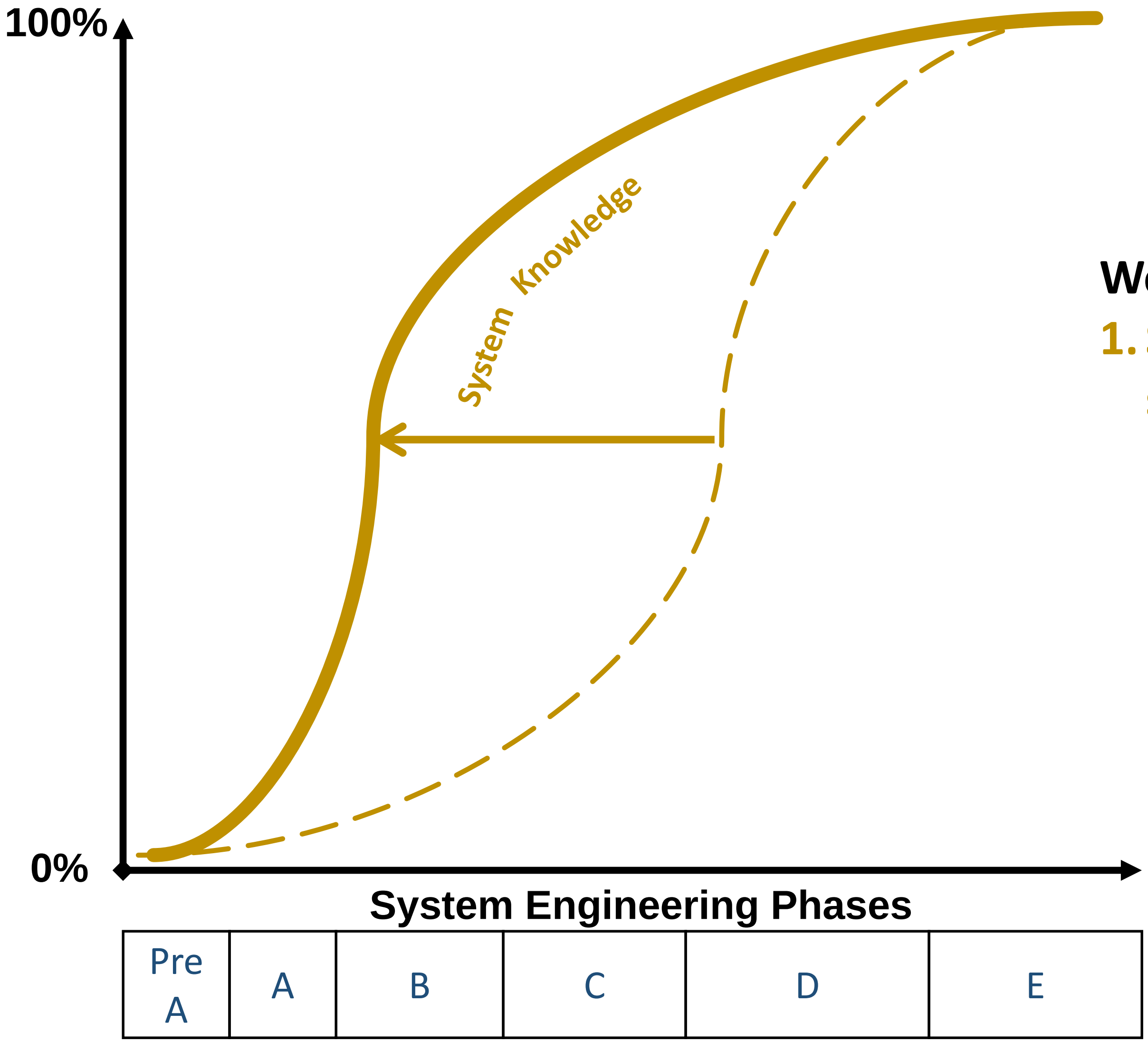
I just defined the cost plan

If I do not respond:

I just lost my project

So, we have some Needs!

Need 1: System Knowledge Earlier



We All Want:

1. **System Knowledge sooner**

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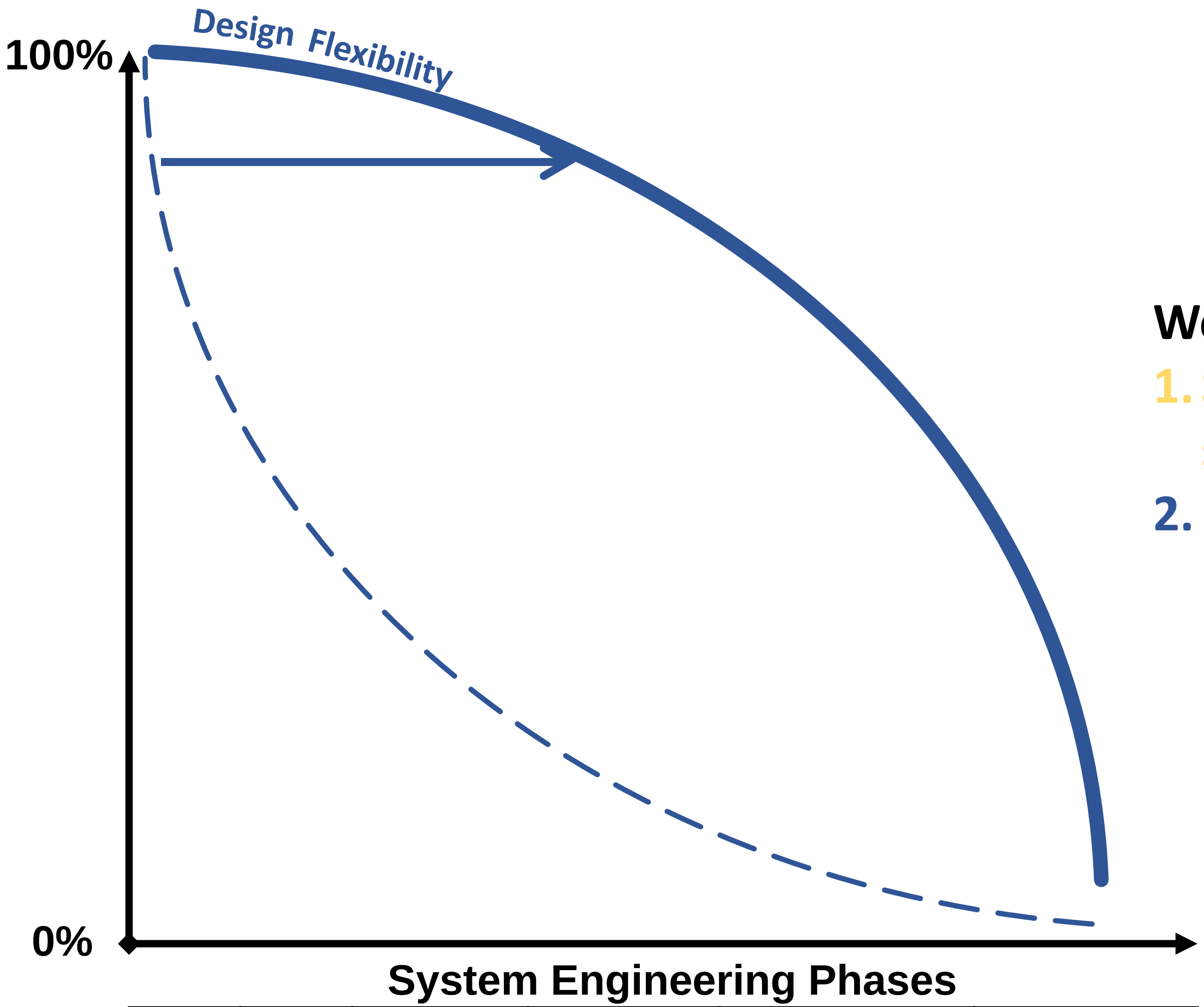
Need 2: Design Flexibility Later

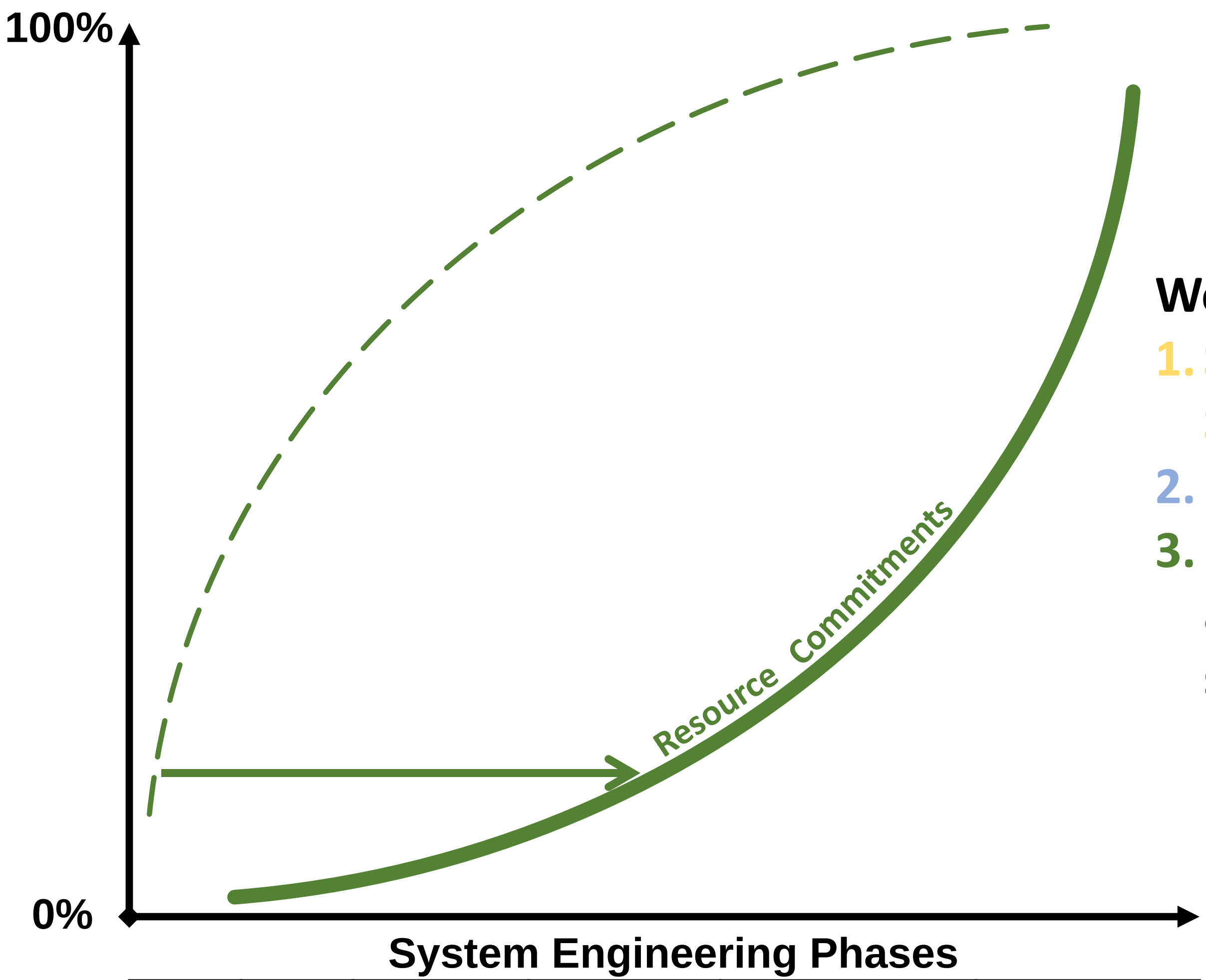


Pre A	A	B	C	D	E

We All Want:

1. **System Knowledge sooner**
2. **Design Flexibility longer**

Need 3: Resource Commitments Later



Pre A	A	B	C	D	E

We All Want:

1. System Knowledge Sooner
2. Design Flexibility Later
3. Resource Decisions after we know something useful

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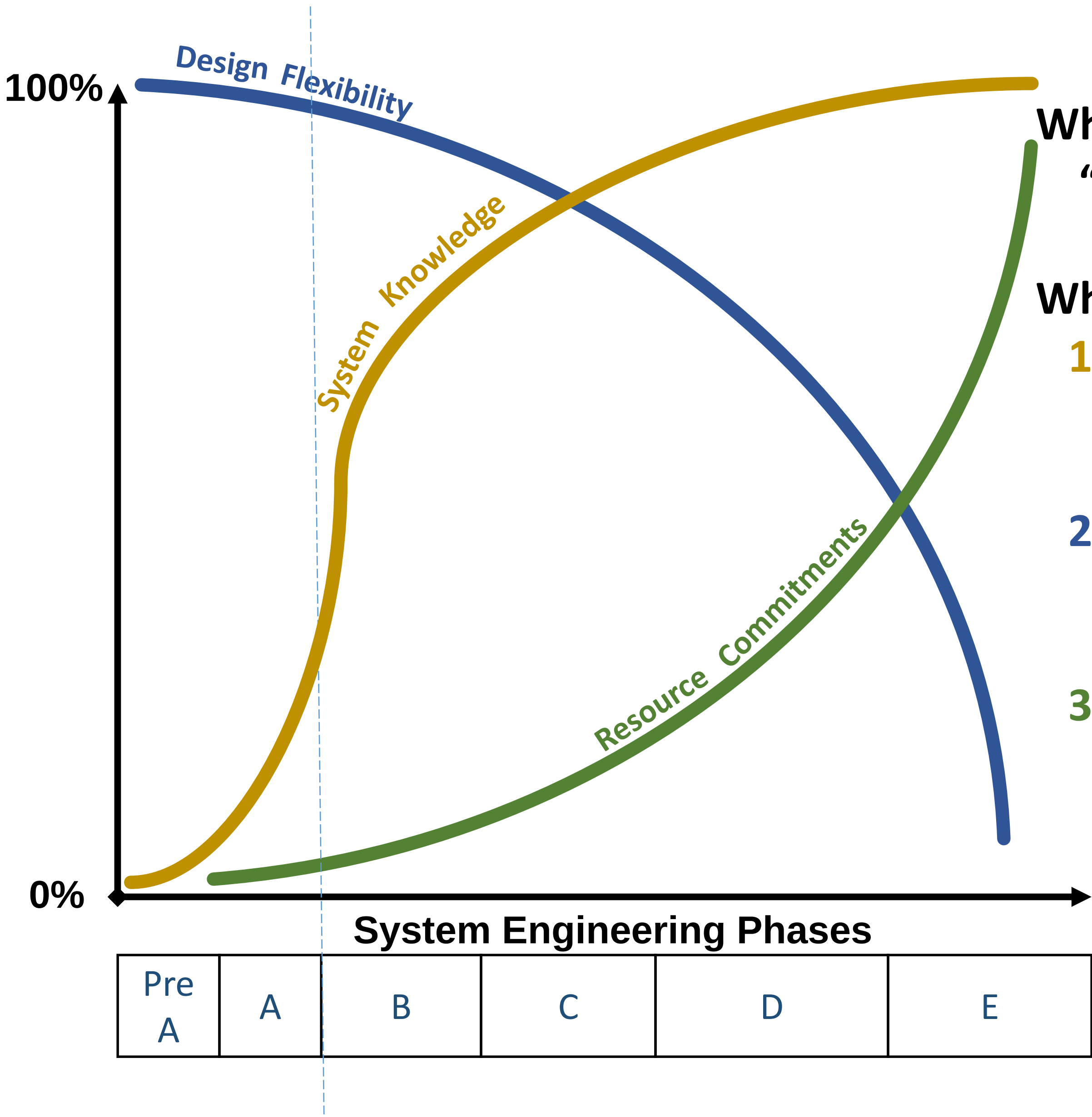
I Really Want …



When Stakeholder asks "What will it look like?"

What "We" Really Want:

1. **I can show you now (Early System Knowledge)**
2. **Then you can help steer me (Still have Design Flexibility)**
3. **And we can look at the financial burn (Still have Resource Options)**

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One Approach

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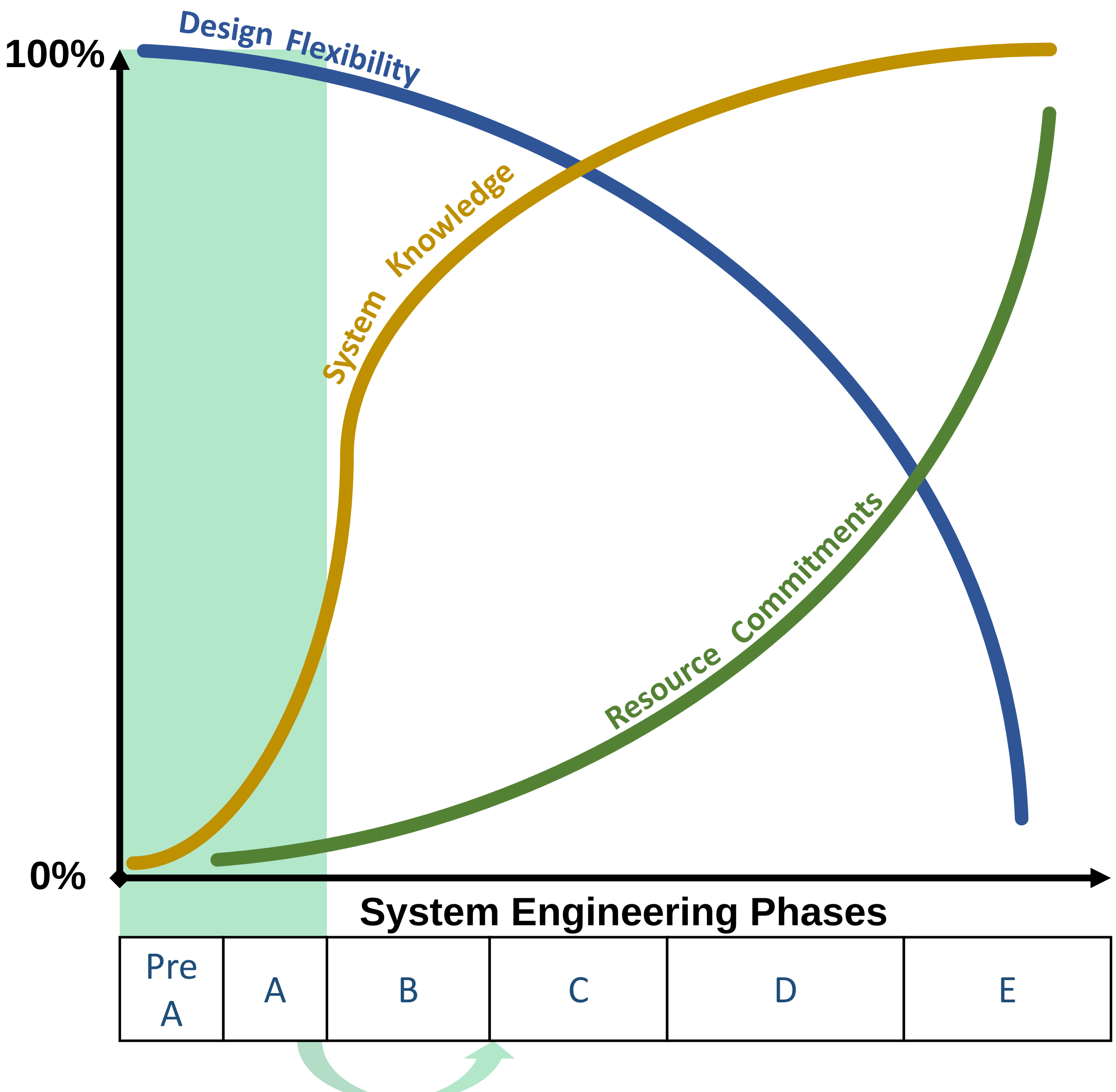
Simulation Based Concepts



Simulation Based Concepts feed Preliminary Design with enough detail to allow Validation at the end of Preliminary Design

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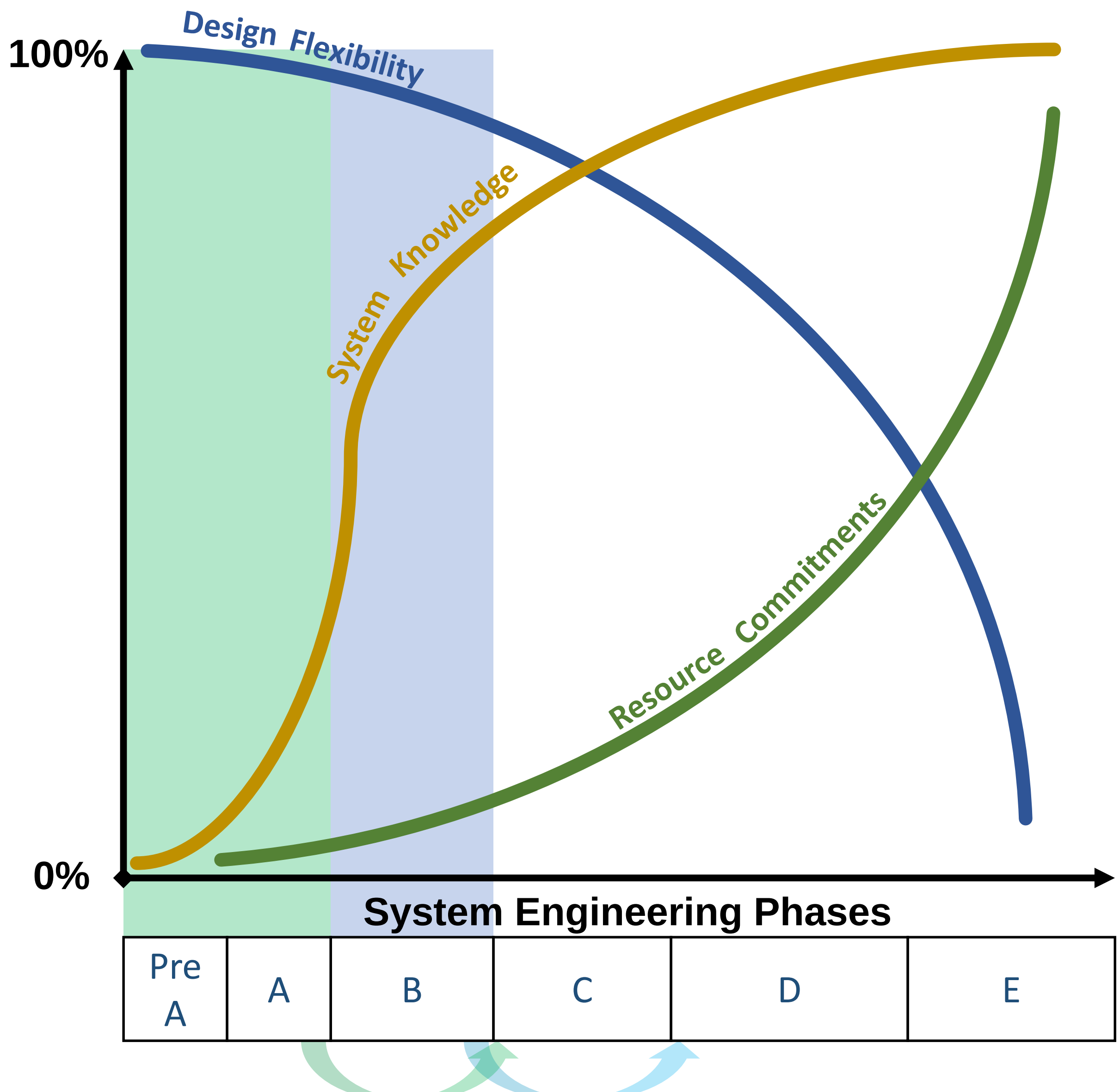
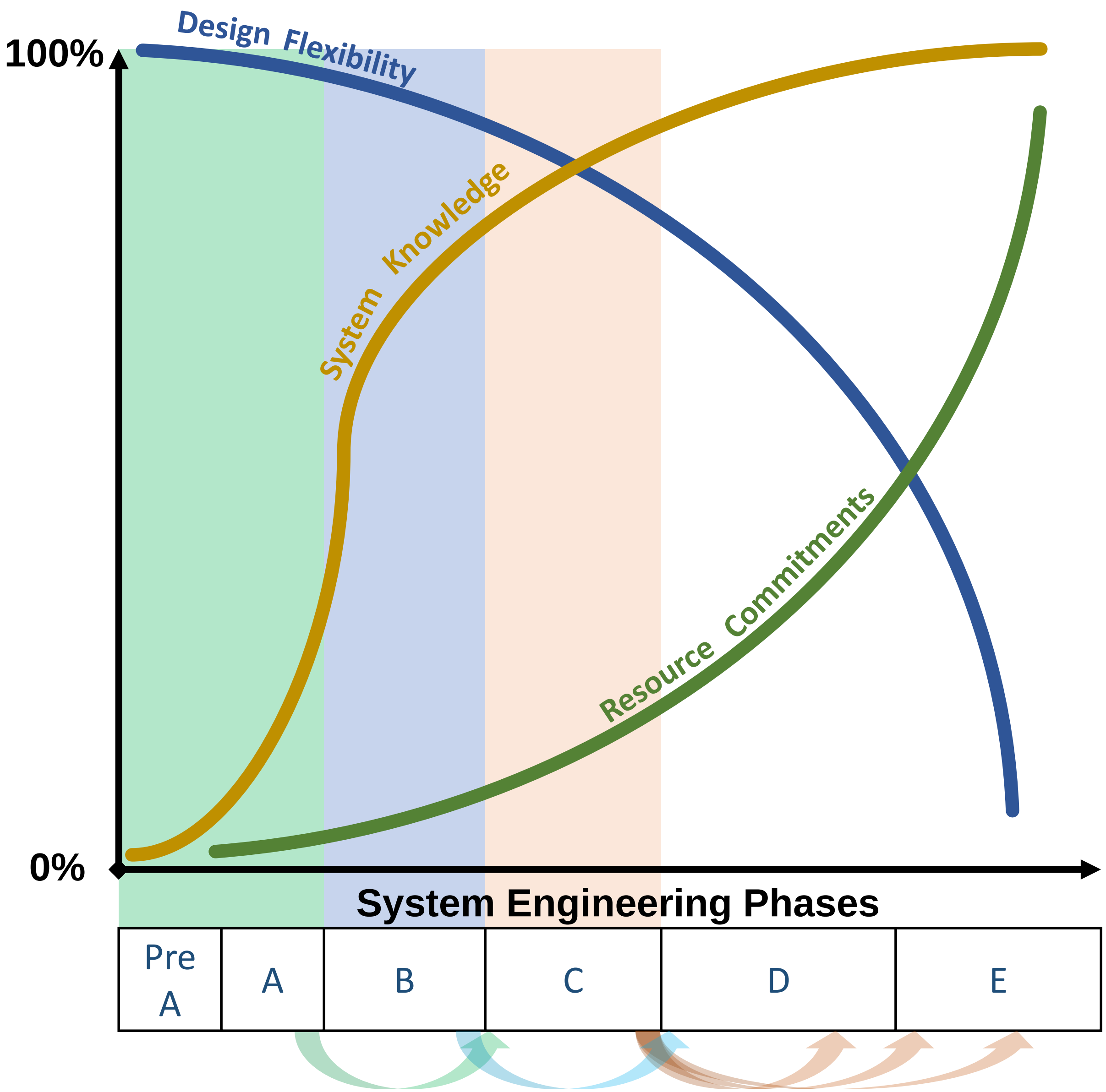
Simulation Based Designs



Simulation Based Concepts feed Preliminary Design with enough detail to allow Validation at the end of Preliminary Design

Simulation Based Preliminary Designs feed Final Design with enough detail to allow Validation at the end of Detail Design, before Fabrication

Simulation Based Systems



Simulation Based Concepts feed Preliminary Design with enough detail to allow Validation at the end of Preliminary Design

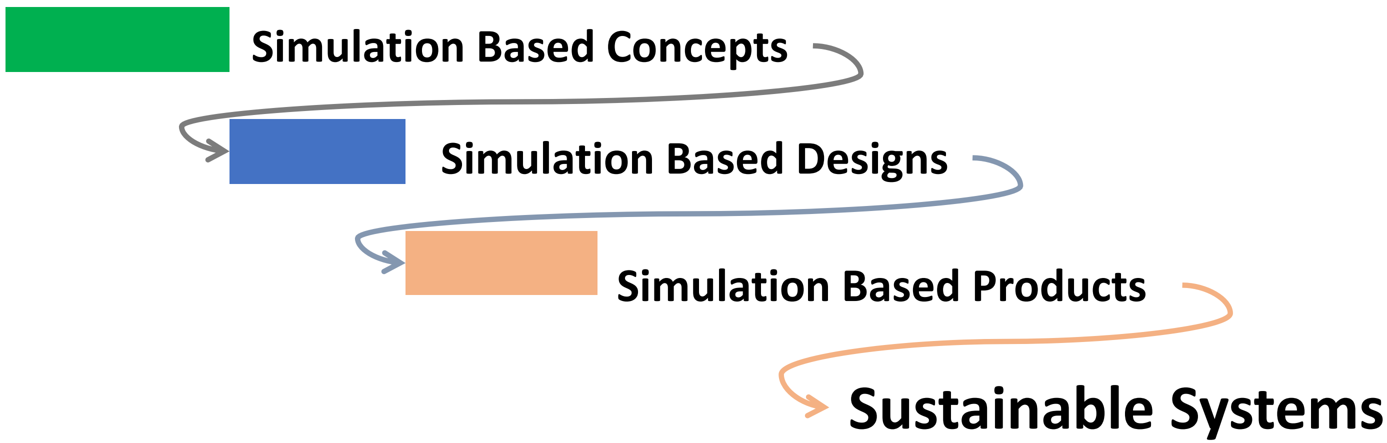
Simulation Based Preliminary Designs feed Final Design with enough detail to allow Validation at the end of Detail Design, before Fabrication

Simulation Based Final Designs feed Fabrication and Operations with Buildable, Operable, Sustainable and Maintainable Products

Sustainable Systems

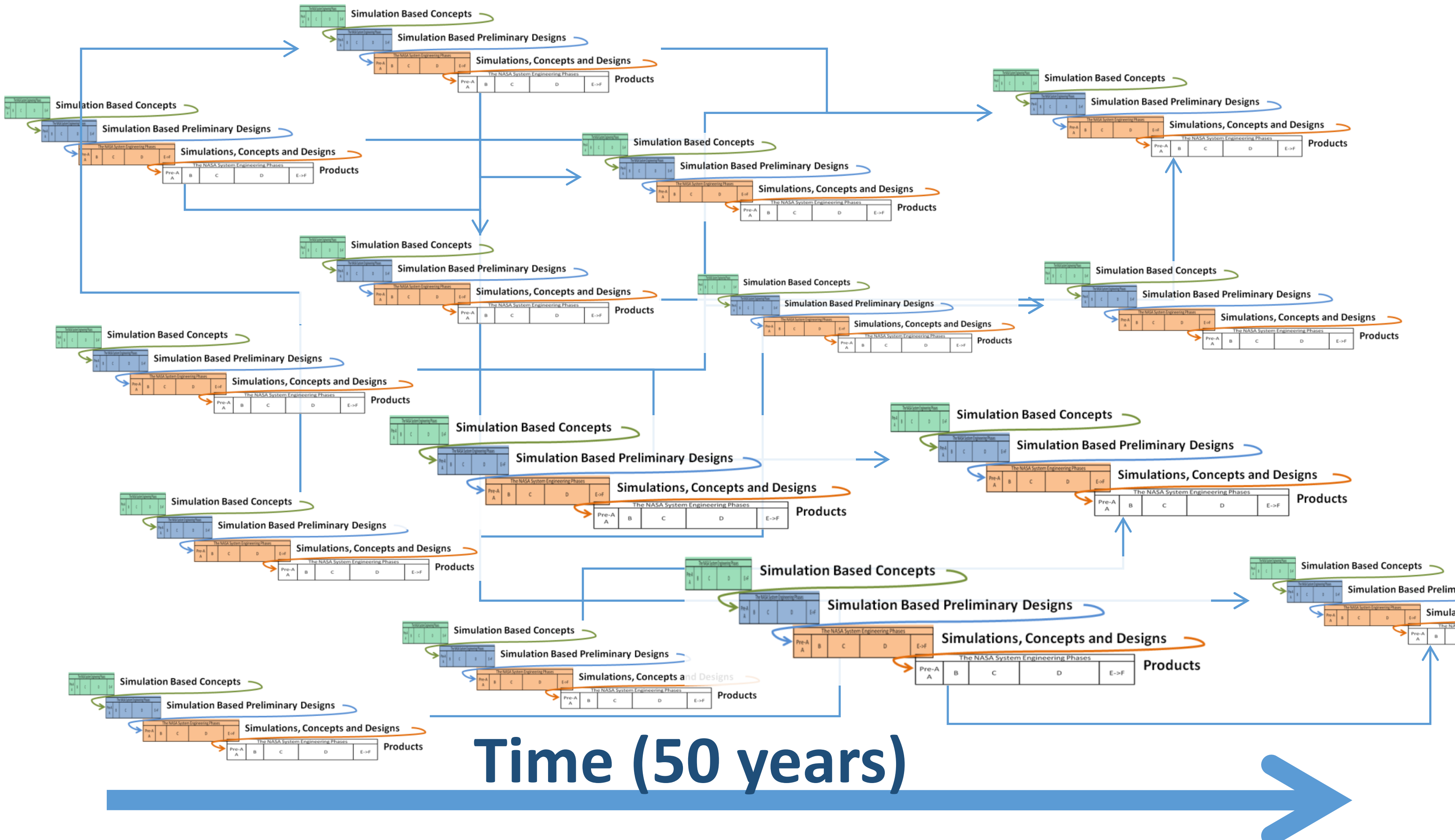
NASA / INCOSE System Engineering Phases

Pre A	A	B	C	D	E



***And**, along the way we create artifacts that we can share, that increase understanding and allow us to access additional expertise*

Multi-Decadal and Interdependent are Hard



Us

Our
Kids

Our
Grandkids

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NASA Modeling and Simulation

mike.conroy@nasa.gov

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Constellation Challenges

- CxP was made up of multiple Projects
  - Each made up of more projects, each made up of even more projects down through multiple program levels
- Those Projects were in various Lifecycle Phases
  - Some had hardware being built, some would not produce systems for years
- Those Projects needed to be able to work together for at least the next 50 years
  - Many generations of humans, teams, programs, partners & tools
  - Not all alive at the same time

Our Assumptions

- There are common elements to communicate
  - Knowledge: Decisions, Experiences, Expertise
  - Information: Reports, Recommendations, Rationale
  - Data: Numbers, Pictures, Models, Equations
- Knowledge is hard
  - It is in peoples heads; they are attached to them
- Information is somewhere in the middle
  - It requires data, but also a lot of other stuff
- Data is fairly easy
  - Just record it; lots and lots of disks
  - Finding it later is another matter, possibly for another generation

Where We Started

- Understand what the elements are
  - What does each look like?
  - Where do they live?
- Understand how the elements behave
  - How do they interact with each other?
  - How do we make it easier for new elements to play too?
- Understand how the elements need to be handled
  - How do we protect them from each other (IP Issues)?
  - How do we best preserve them for the future?

MaST Approach

(CxP Modeling and Simulation Teams)

A Communication Observation

Or

Very Large Bolts

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MaST View of Knowledge

- It is created through experiences
  - What did they look at? How did they use it?
  - Who was involved? What did they learn?
  - What did they know when they started?
  - What tools did they use? When? Which Versions? What Inputs?
- It lives in the people involved in the experience
  - The test team, the analysis team, the decision makers
- It is by far the hardest component to manage
  - It is very often based on "Being There"
  - Everyone cannot "Be There"

MaST View on Information

- It is distilled from the data provided by the tools.
  - Analysis Results
  - Recommendations
  - Supporting Rationale
  - Risk Assessments
- It lives in the documentation provided by the process and the associated CM systems
  - Test Results, Test Reports, Presentations
  - These tools have demonstrated their ability to publish their information for use by others

MaST View on Data

- It comes from the analysis tools being used across Constellation
  - Pro-E for the flight vehicles
  - Arena and Extend for the integrated supply chains
  - Delmia for the integrated process analysis
  - IMSim for integrated system simulations (multiple parties)
  - ScramNET for Launch Vehicle dynamics
- It lives in these tools, files and CM systems
  - DDMS(s), Common Model Library(s), WIKI(s), ICE
  - These tools have demonstrated they can publish data for use in other systems

Where MaST Found Them

- Look at a sample of Constellation Tools
  - Find where each is stored
  - Map how they flow through the system
  - Identify how to get them out
  - Normalize so others can see if their K, I or D can play
- We noticed some tool/location groupings
  - Some live in Physics Based Tools
    - System State Information, Structural Information
  - Some live in Physical Environment Tools
    - Temporal / Spatial Information
  - Some live in Supply Chain Tools
    - What you need when you need it (that is a different KEA)

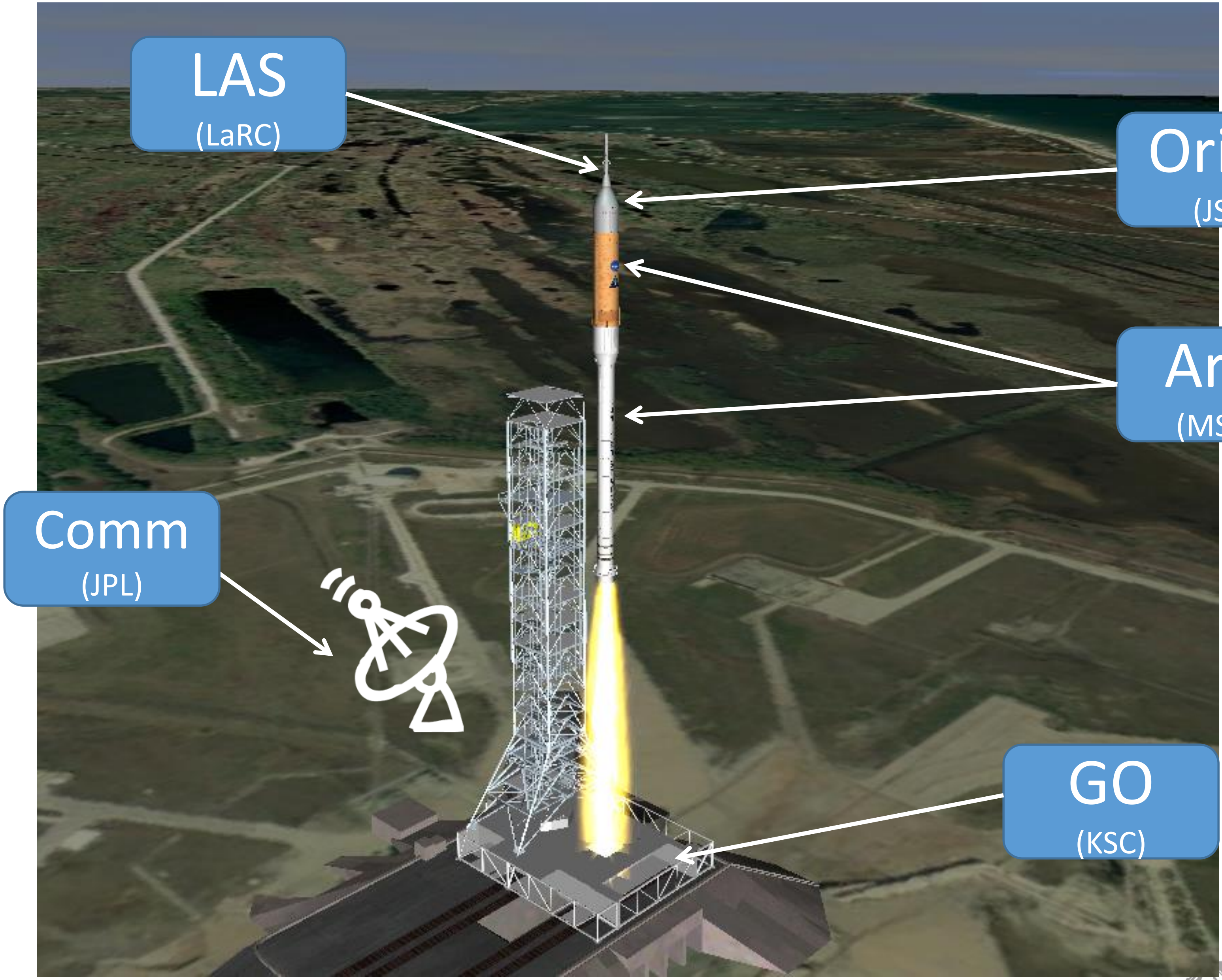
Physics / Physical Tools (State, Time, Space)

- Primarily related to the Flight activities
  - Launch Preparations, Flight and Post Flight
  - Start with Guidance, Navigation and Control
  - Extend to Flight Dynamics as needed
  - Extend wherever else is needed.
- Physics Based Motion, Accompanied by Necessary Graphical Elements.
  - Physics Based Launch, Ascent, Dock, Entry, Descent, Landing, Recovery, Retrieval
  - Couple with High Resolution Graphics For Human in the Loop Test and Evaluation

Mission Simulations

- Modeling and Simulation Labs (MSL) #1
  - A full flight simulation to ISS
- Virtual Mission (VM) #1
  - Add in build, prep and test phases, then fly
- The MaST Piece (Ares, Orion, Gnd Ops, LAS & ISS)
  - Teach the Projects to talk to one another
    - MAVERIC and ANTARES on Flight Side
    - Ground Operations Simulation
    - LAS Simulation and ISS Simulation
  - Let People and Simulations talk to one another
    - High Level Architecture, TRICK, DSNet, DON

Ares 1 Launch Sim (HLA, Trick, 5 sites)



Simulation Speeds Communication

- It is non-threatening ('ish).
- Leadership is not wrong, I just need their help to get the simulation right.
- Or, everyone is wrong, and we need to know now.
- Imagine 3 people vigorously discussing what turns out to be 3 different concepts
  - **The worst thing that can happen is that they come to an agreement and leave happy**
  - Simulation can help ensure everyone is at least in the same argument, and it leaves a record

Communication Successes

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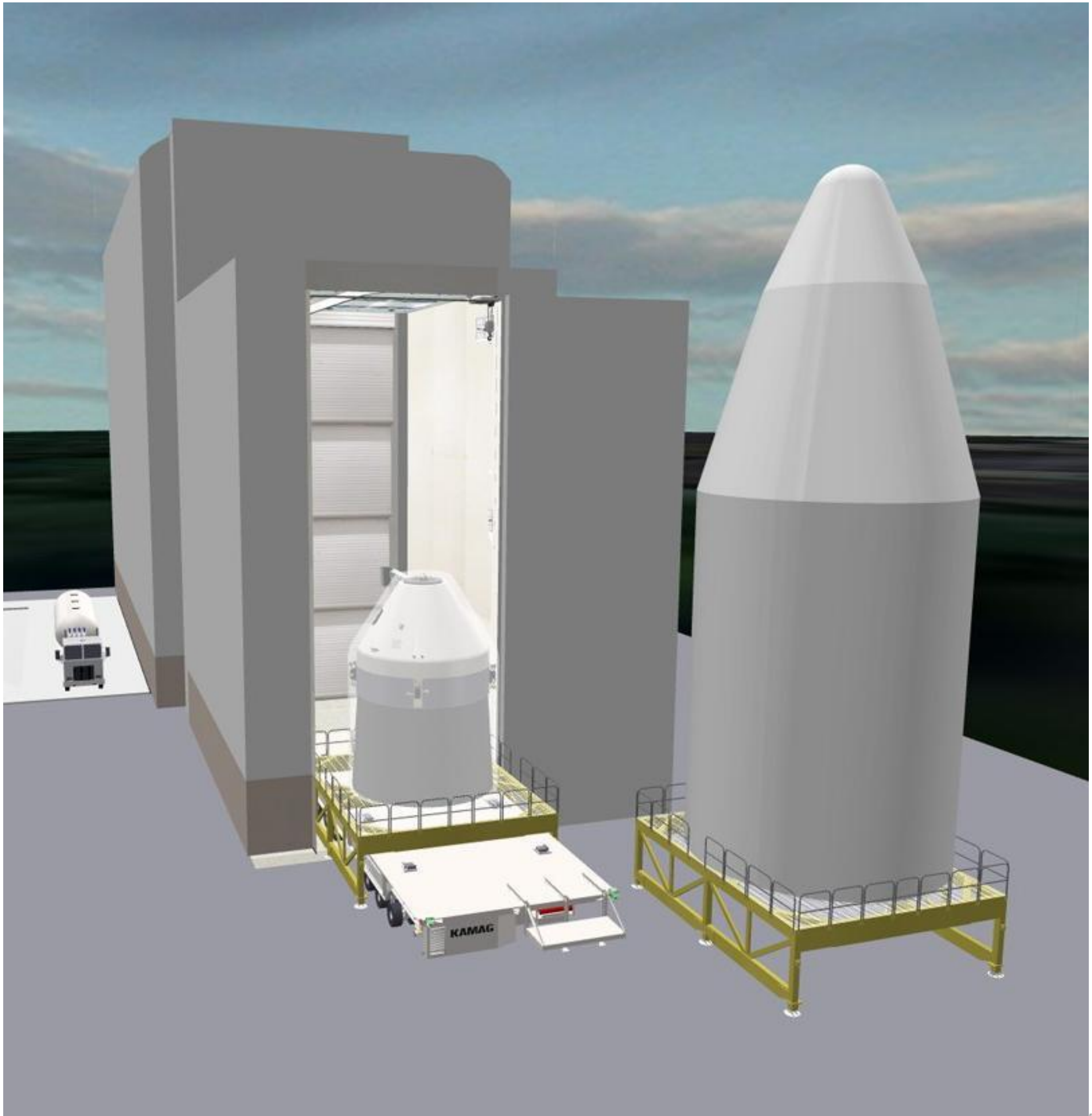
NASA



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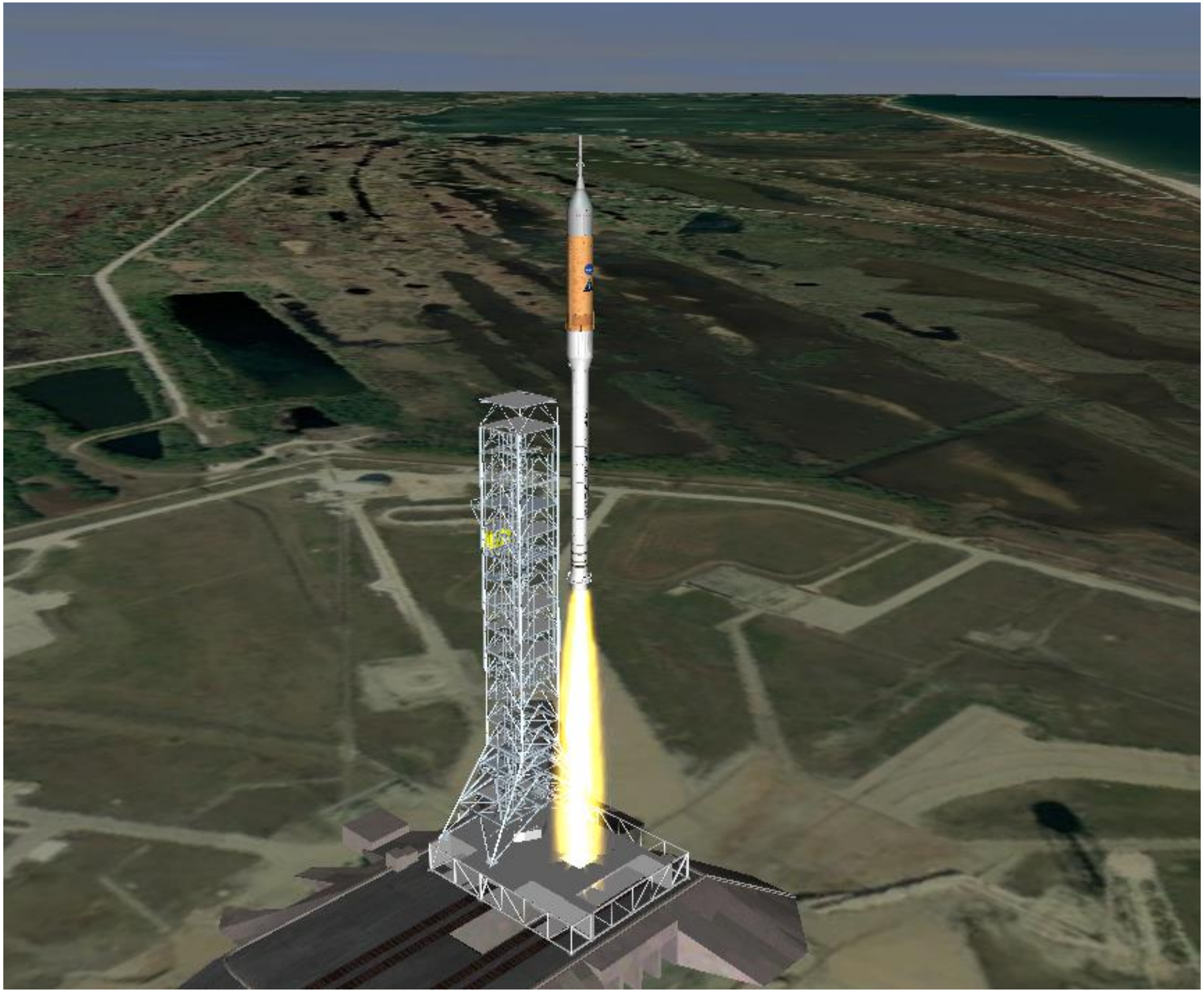

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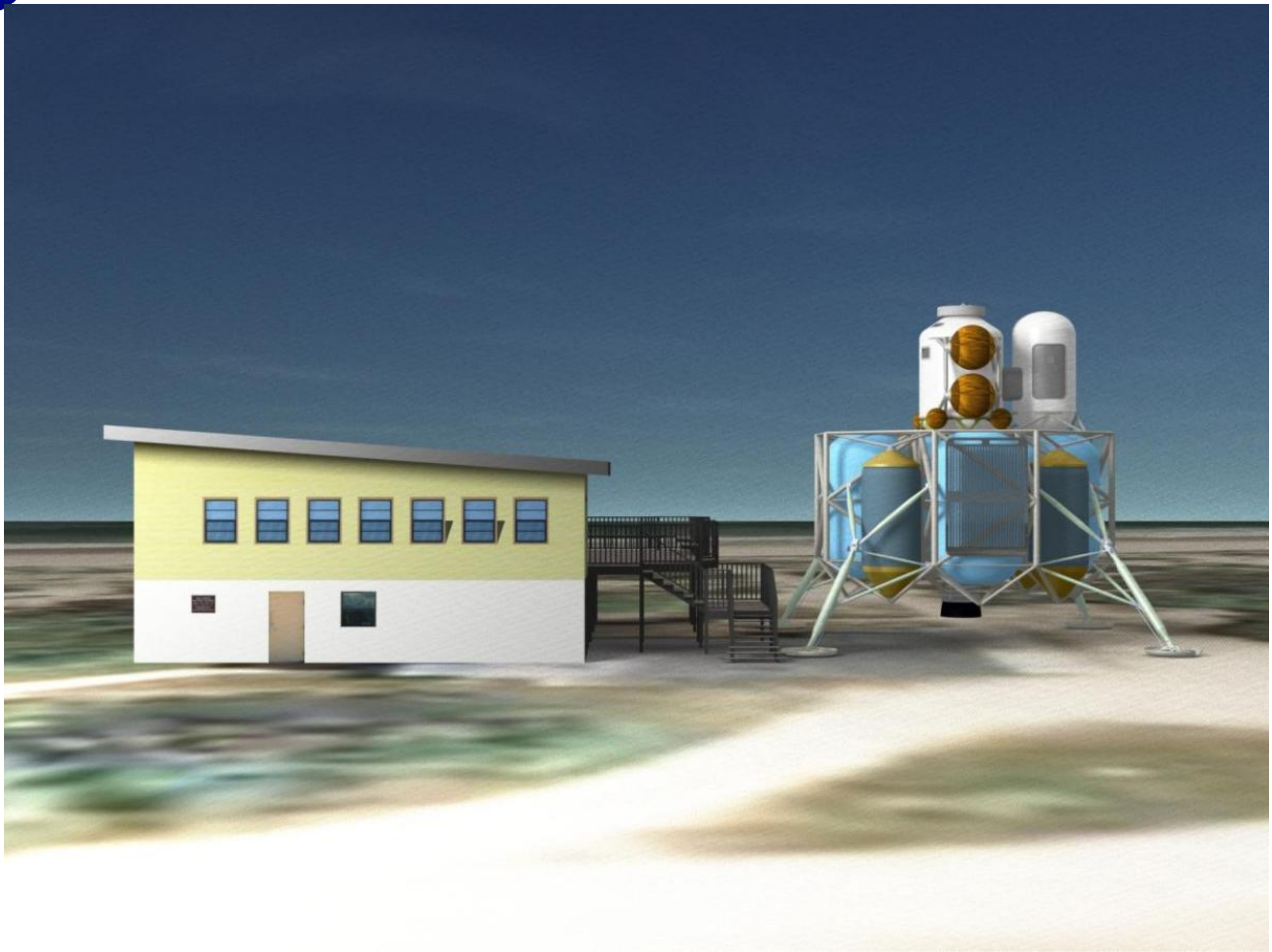

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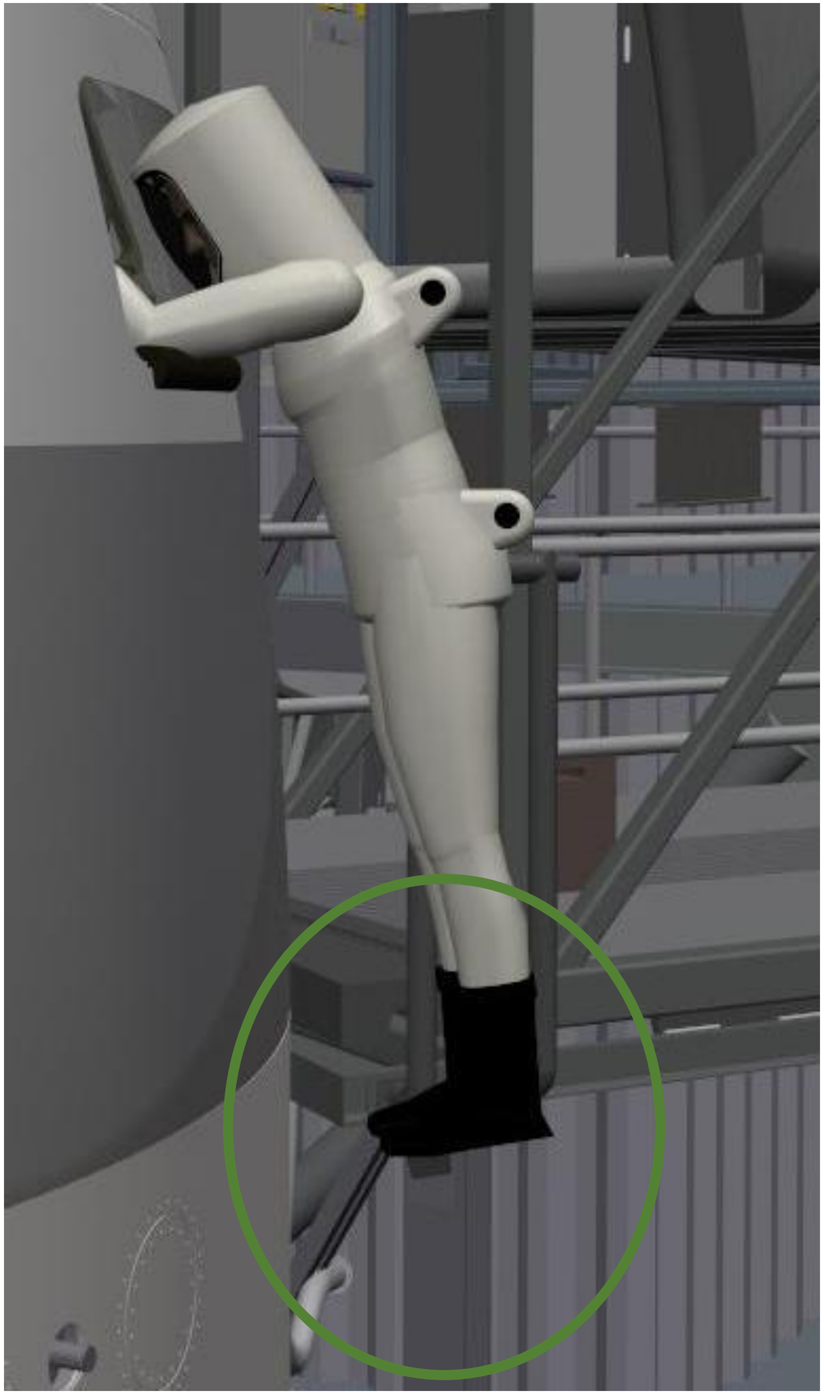


Preserve Knowledge for the Future

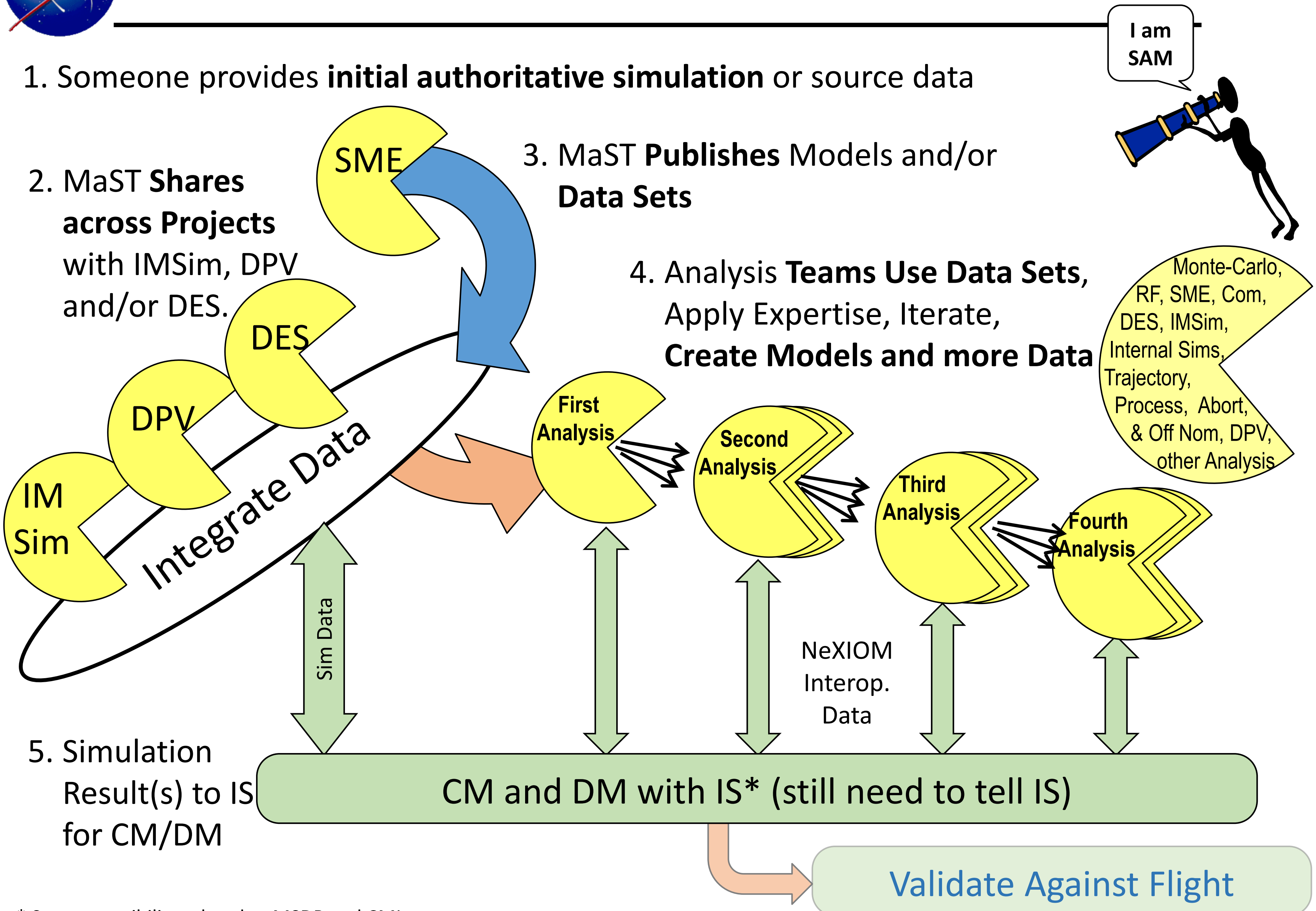
- All of this Data was going to Info Services
  - They were providing more and more services every day
  - Their tool (Windchill) was well suited to this type of data
    - Indentured Parts really close to Hierarchical Data
- To Transfer Knowledge, it helps to re-experience learning
  - If Simulation Based Learning, you must re-experience the simulations that developed the Knowledge
  - This is very difficult when the simulation computers, software, people and systems are gone
  - How do you save the Simulations for future generations?

Simulation for Future Generations

- This was a key mission for the Data Presentation and Visualization (DPV) Element
  - Simulator provides 4-Dimensional data from the simulation used to make decisions, as well as key measurements, images and Meta-Data
- The Simulation can now be replayed as needed
  - Without need for the simulation infrastructure
  - Whenever and Wherever needed; the goal is to be able to do this forever
    - Ground, Flight, Moon, Mars

This Enables a LOT!

1. Someone provides **initial authoritative simulation** or source data
2. MaST **Shares across Projects** with IMSim, DPV and/or DES.
3. MaST **Publishes** Models and/or **Data Sets**
4. Analysis **Teams Use Data Sets**, Apply Expertise, Iterate, **Create Models and more Data**
5. Simulation Result(s) to IS for CM/DM



* Strong possibility related to MSDB and CML

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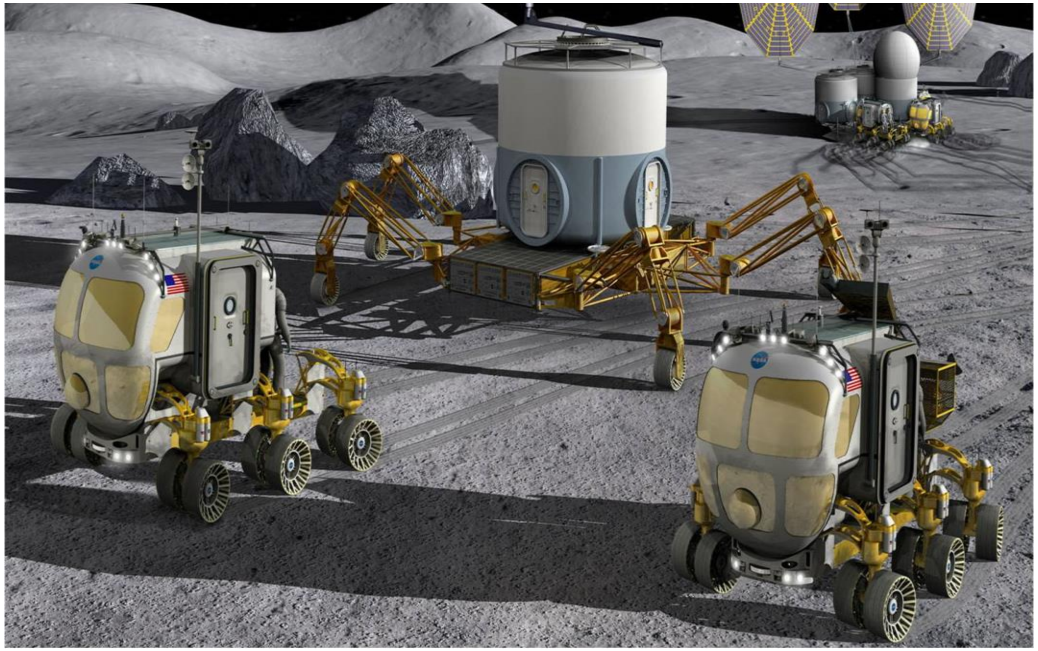


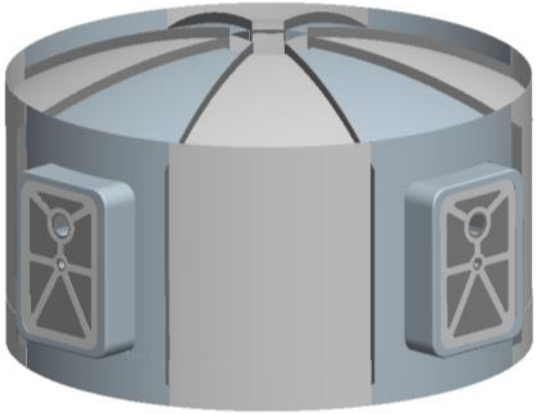
Concurrent Design Observation

Habitat Demonstration Unit

HDU Overview

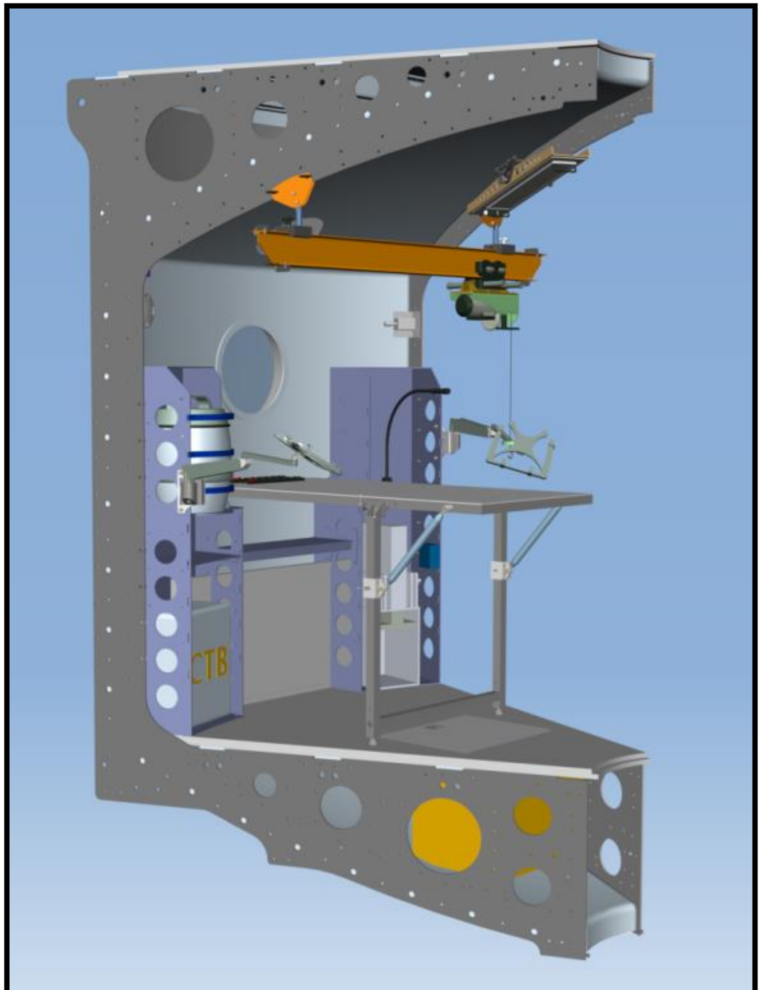
- Vision
  - Develop, integrate, test, and evaluate a Habitation prototype to better understand mission architectures, requirements and operational concepts
- Timeline
  - Project Kick-off: **June 2009**
  - Shell: October 2009 – April 2010
  - Systems Integration: **April – August 2010**
    - 10 Month Build, 4 Month Integration
  - Field Test at Desert RATS September 2010
- Participation
  - Jointly managed and built across 3 Time Zones with subsystems from 7 Centers

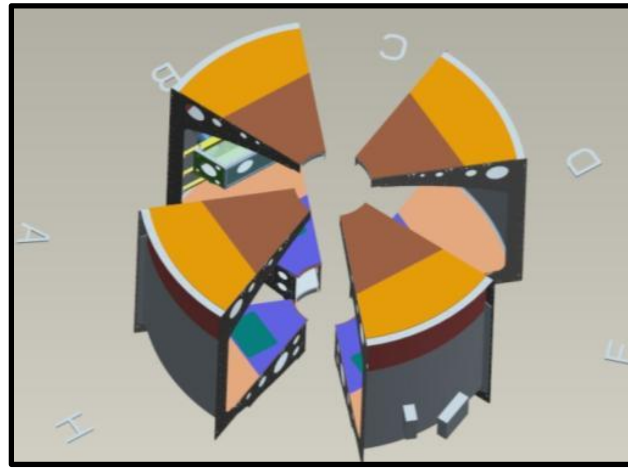
Lunar Reference Concept (PEM)

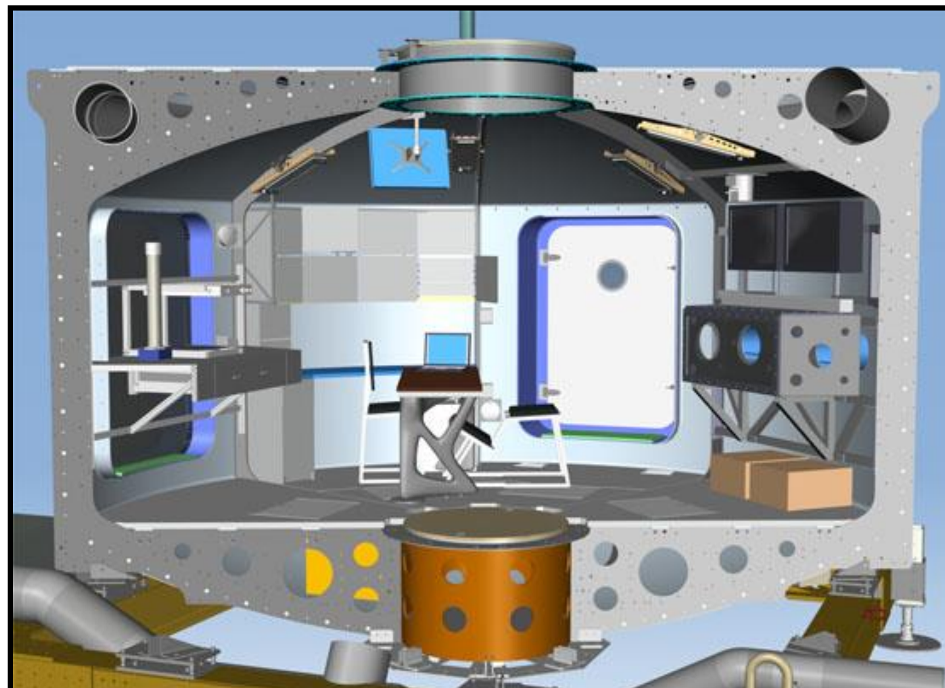


HDU Concept

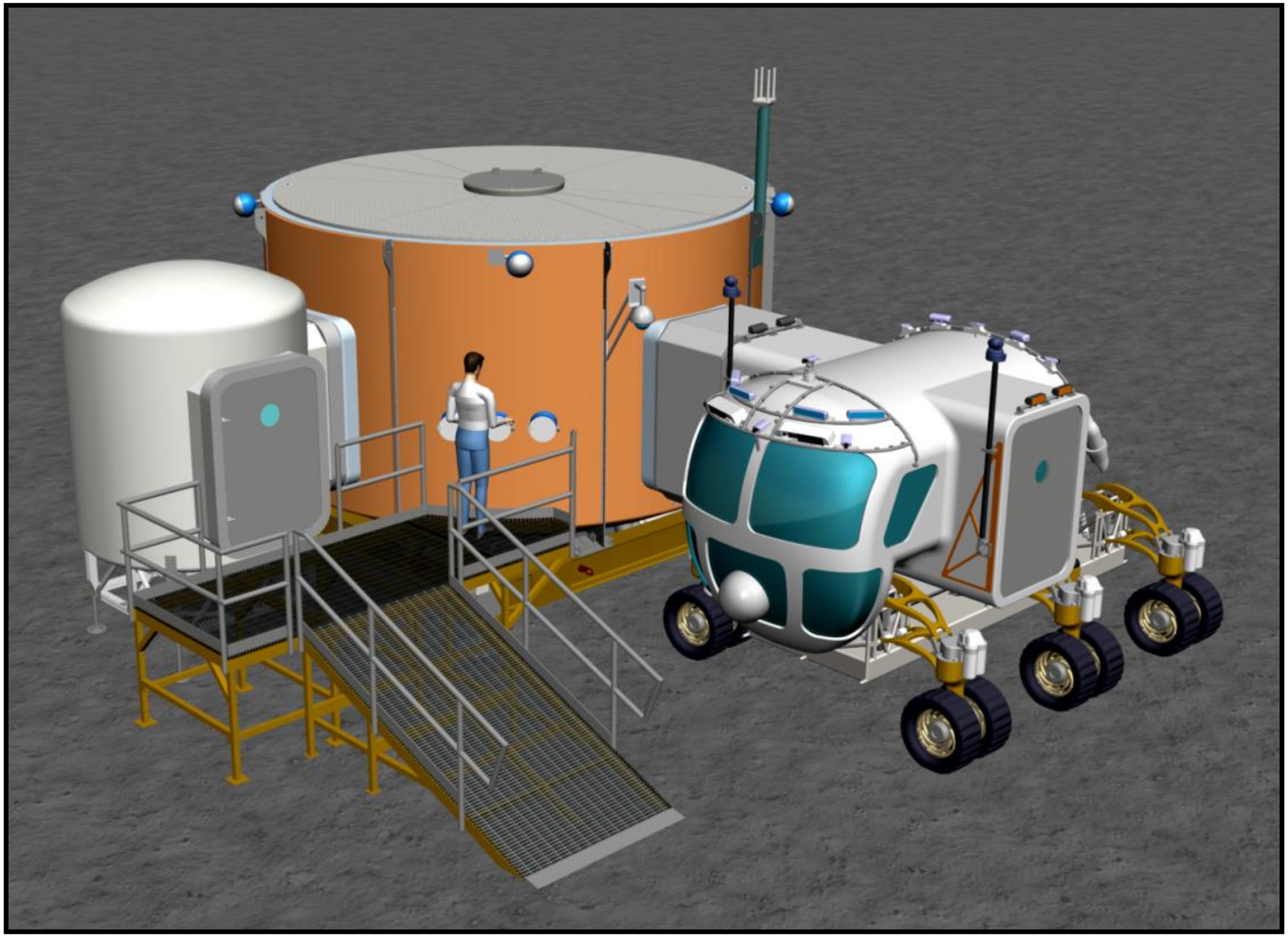
CAD Based Integration - Interior







CAD Based Integration - Exterior



Concept Realization (15 Months to Field)

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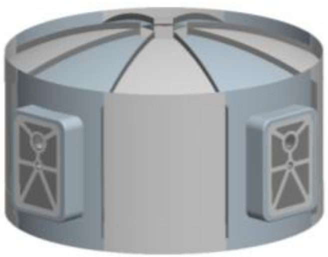

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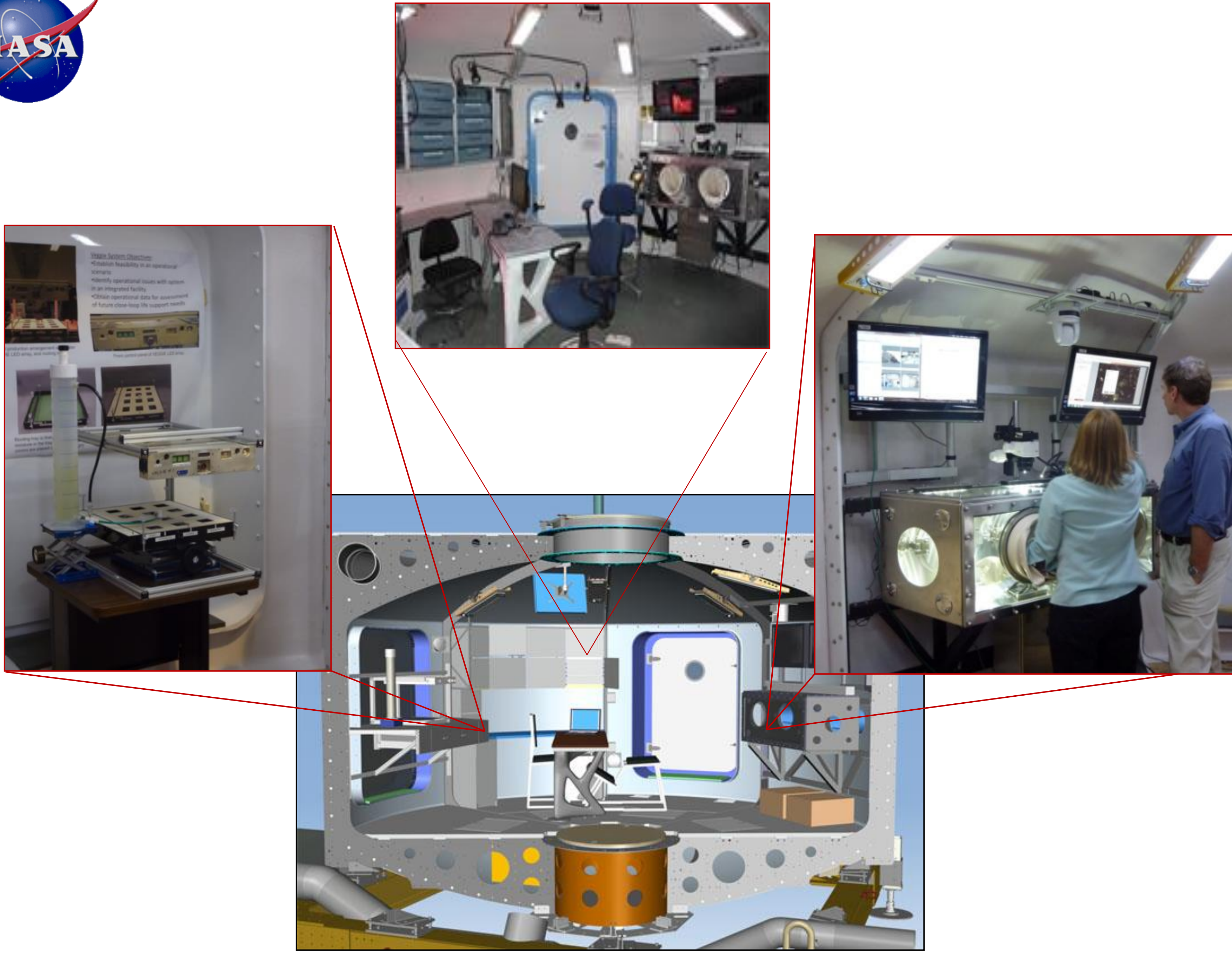

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Concurrent Design Lessons

- CAD integration rapidly grew to system simulation, then concurrent development
  - Concepts were matured in design sessions
    - Concept developed, “model” updated, package base lined
    - Design completed, “model” updated, systems built
    - Multiple Centers, Teams, Projects, Time Zones and Budgets
- **Success not just because of Simulation**
  - **<u>HDU leadership prioritized decisions such that time critical elements were decided on first</u>**
    - **Even if only allocations**
  - **Simulation Screen Shots became a key communication path**
    - **Timely, Enhanced Understanding, Converged Ideas**

Concept

Design

Development

Done

This Might Work Observation

SEE 2015, a template for integrated exploration

Simulation Exploration Experience

- Cooperative Student Event
  - US, Canada, Europe so far
  - Simulate a Lunar Base with NASA Tools
    - HLA (MAK, Pitch, Forward Sim)
    - Trick (NASA Open Source)
    - Federations (rovers, flyers, surveyors, buildings, terrain)
    - DON, Distributed Observer Network (Game Based Visualizer)
    - Model Process Control data, creates persistent simulations

- We would welcomes others…

Data from SEE 2015 Event

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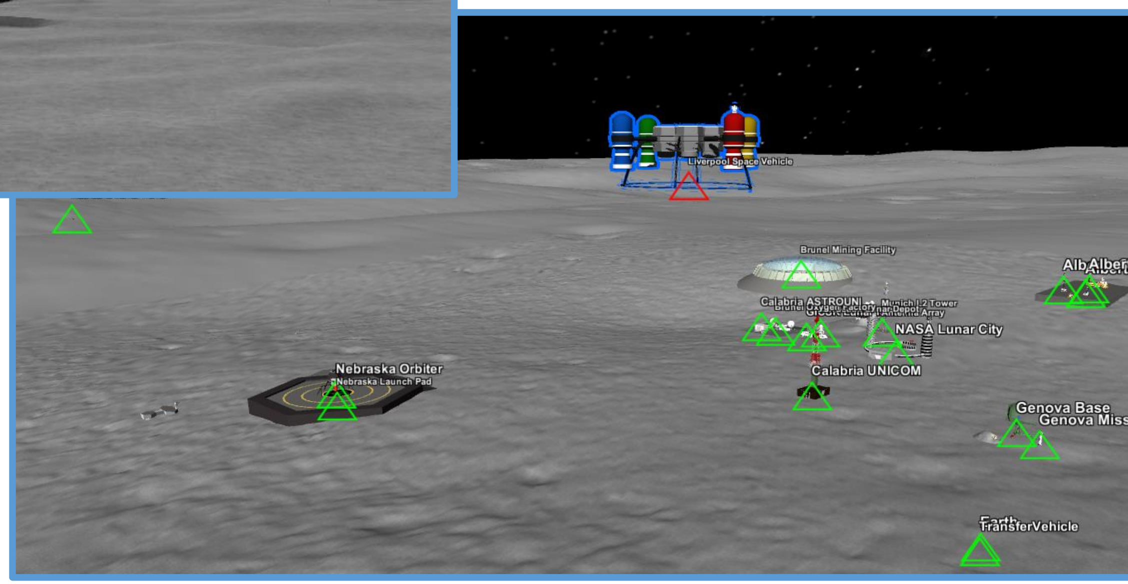


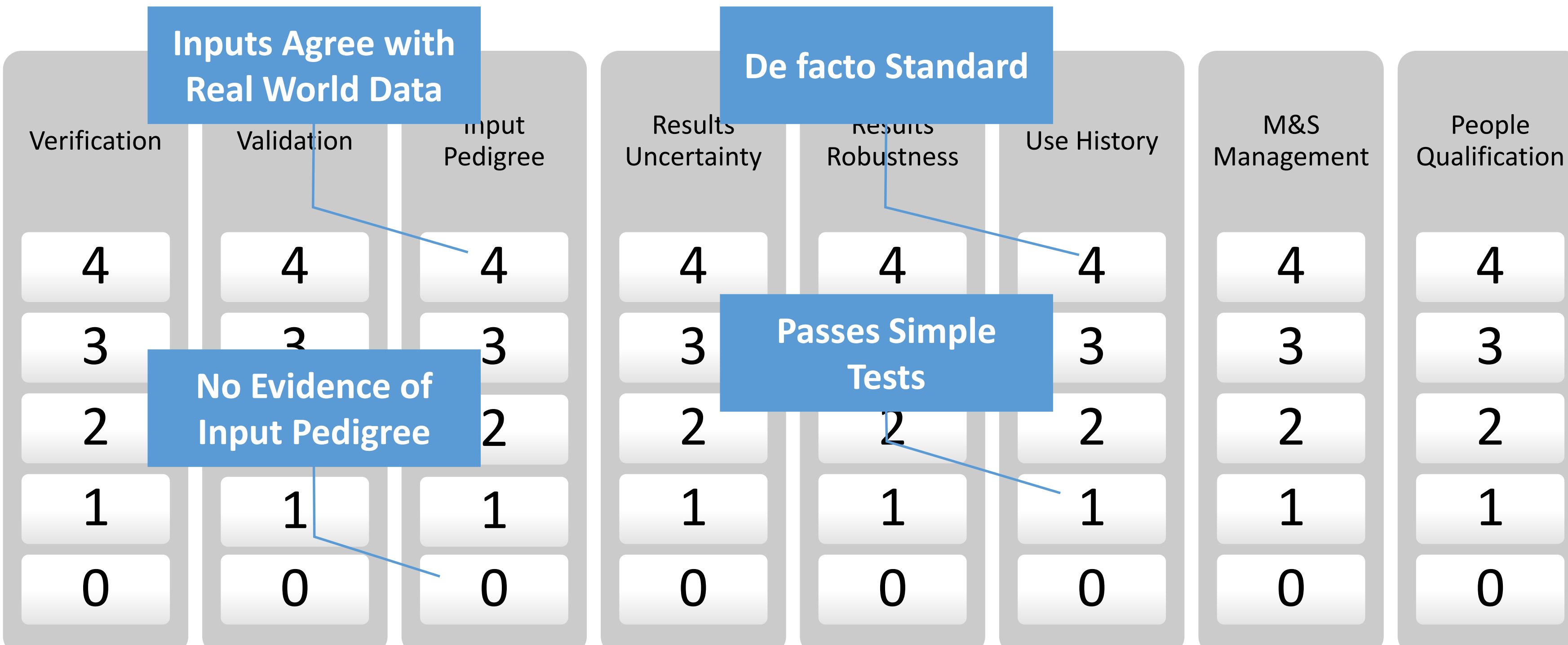
A Quick DON / SEE 2015 Demo

Self Grading Observation

NASA Standard 7009, Modeling and Simulation

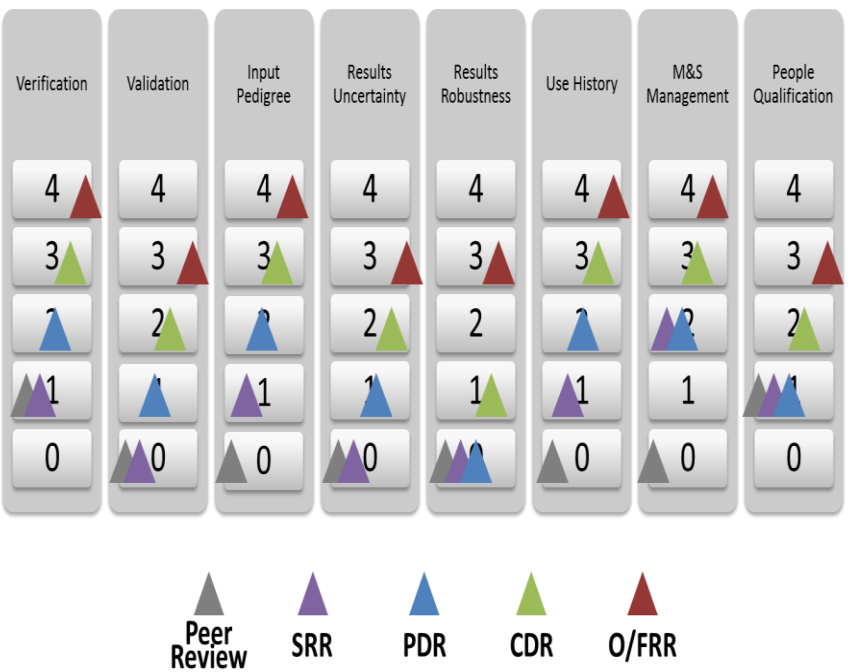
The Numbers on the Score Sheet

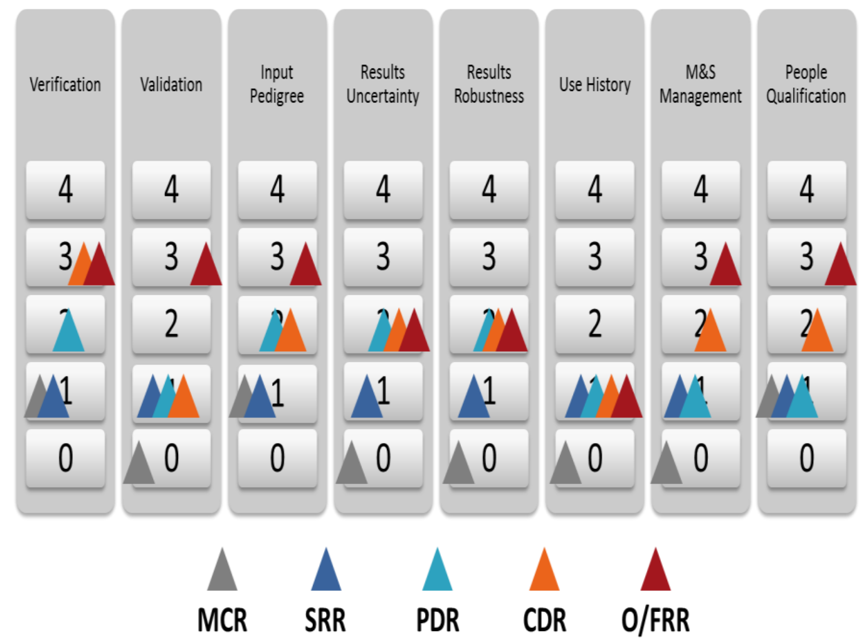
- To communicate the rigor, fidelity and pedigree of our work (Credibility), across distance and years
- We used NASA Standard 7009
  - 8 categories, 5 levels per category
  - Range from "No Evidence" to "Best Possible" Credibility



As Programs Mature, Credibility Increases

- Compare the planned Constellation (crewed, left) maturation with a flight experiment (no crew, right)
  - The experiment first pass has higher credibility, but the end result is only 2’s and 3’s.
  - They do more work up front before commitment, but do not need the later, expensive, high fidelity simulations.





SEE 2015 CAS Score = 0-1-0-0-0-1-1-1

	Verification	Validation	Input Pedigree	Results Uncertainty	Results Robustness	Use History	M&S Management	People Qualification
4	Reliable error estimates used, small errors across key elements	Results compare favorably to real-world system	Inputs agree with real-world data or from > 3.5 summary M&S	Quantitative and based on Non-deterministic & numerical analysis	Sensitivity known for most parameters (all of the most sensitive cases)	De facto standard	Continual process improvement to improve result repeatability	Extensive experience and use of recommended M&S practices & tool
3	Formal method is used to assess unit testing errors	Results agree with experimental data for problems of interest	Inputs agree with exp. data for problems of interest or from > 3.0 summary M&S	Quantitative and based on Non-deterministic analysis	Sensitivity known for many parameters	Previous predictions were later validated by mission data	Process measured for repeatability	Adv. degree or extensive experience, recommended practice knowledge
2	Favorable results from key feature unit / regression testing	Results agree with experimental data or other M&S on unit problems	Inputs traceable to formal doc., or from >2.0 summary M&S	Based on deterministic analysis or expert opinion	Sensitivity known for a few parameters	Used before for critical decisions	Established process for development and operations	Formal M&S training and experience + recommended practice training
1	Favorable evidence of verification for concept & math models	Concept and math models agree with general and textbook referents	Inputs traceable to informal doc., or from > 1.0 summary M&S	Based on qualitative estimates	Sensitivity estimated, qualitative, based on analogy	Passes simple tests comparing with other similar tools	Roles and Responsibilities defined and managed	Engineering or science degree
0	No Evidence	No Evidence	No Evidence	No Evidence	No Evidence	No Evidence	No Evidence	No Evidence

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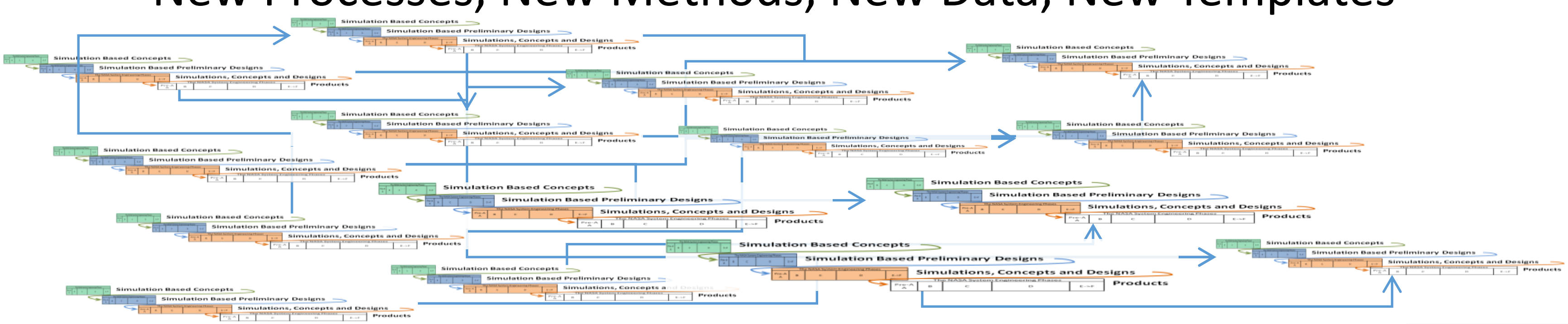
Standard Grades

- This lets engineers, scientists, analysts and others identify what they created, and what it could be used for.
- It also lets leadership understand what something should NOT be used for.

Conclusion:

- Modeling and Simulation is a key technology for understanding system life cycles and their complexity
- M&S helps represent systems and interfaces
  - Physical, Logical, Financial
- M&S helps understand dependencies
  - Across systems, programs, projects and decades
  - Within systems, programs, projects and decades
- M&S alone is not the answer
  - New Processes, New Methods, New Data, New Templates



Going Forward

- Just wanting to meet huge new challenges is not enough
  - We must learn how to start meeting them today
    - With our partners, **wherever they are**
  - We must enable our children to finish tomorrow
    - Simple and persistent mechanisms to communicate with them **whenever they are**
- We must Learn how to Play Nice Across Space and Time

Questions?

More Observations?

Backup Stuff

Persistent Simulation

- Persistent Simulation for Multi-Decadal Teams
  - Or, Playing Nice Across Time and Space

- Bio – Mike Conroy / Modeling, Simulation, IT Technology Manager / Kennedy Space Center
  - Experience from Expendable Launch Vehicles, Space Shuttle, a multi-year sentence in financial management, computer networks and data systems, engineering environments, contracts, group management and Modeling and Simulation for the Constellation Program.
  - Now leading Kennedy Simulation and IT Research management while building simulators and game based tools for NASA Exploration efforts.